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AGISTEMUS EXSERTUS GONZALEZ (ACARI: STIGMAEIDAE) AS A PREDATOR OF CITRUS RED MITE (*PANONYCHUS CITRI* [MCGREGOR])

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Abstract.—The potential of using *Agistemus exsertus* to control *Panonychus citri* was studied in both laboratory and citrus grove. Functional response studies showed that *A. exsertus* adult females had the highest instantaneous rate of discovery (a = 1.430) and shortest handling time (Th = 1.67 hr) when provided with *P. citri* eggs as compared to other prey stages. In comparison with adults of both sexes, *A. exsertus* deutonymphs had the lowest a (0.102) and longest Th (4.32 hr) when *P. citri* eggs were provided as prey. *A. exsertus* females clearly exhibited a prey-stage preference; an average of 75.2% of prey consumption consisted of eggs as compared to 16.6 and 8.2% nymphs and adult males, respectively. The intrinsic rates of natural increase (rm) of *A. exsertus* were higher at 20 and 25°C, but lower at 30 and 35°C than that of *P. citri*. *A. exsertus* demonstrated a satisfactory control of *P. citri* in the greenhouse release study. Under natural conditions, the population of *A. exsertus* was very low in the winter and increased steadily from May through October.

Since mid 1930 more than 300 species of Stigmaeidae have been described (Sepasgosarian, 1985, 1990). The biology and predacious potential of the individual members of this family were not initiated until recent years (Elbadry et al., 1969a). Some species in the genera *Zetzellia, Agistemus,* and *Mediolata* were known to prey upon phytophagous mites of *Tetranychidae, Tenuipalpidae, Eriophyidae, Tydeidae,* and *Tarsonemidae* as well as some small insects (Tseng, 1982; Inoue and Tanaka, 1983; Ehara and Wongsiri, 1984; Clements and Harmsen 1990). Santos (1984) considered *Z. mali* (Ewing) to be the most significant nonphytoseiid predator of phytophagous mites. It was used as a regulating agent of *Panonychus ulmi* (Koch) and *Aculus schlechtendali* (Nalepa) in apple orchards (White and Laing, 1977). Childers and Enns (1975) reported that *A. fleschneri* Summer fed on all stages of tetranychid mites but preferred their eggs. In recent years, considerable research has been done to evaluate *A. exsertus* as a predator of such species as *Tetranychus cinnabarinus* (Boisduval), *T. arabicus* Attiah, *T. urticae* (Koch), *T. cucurbitacearum* (Sayed), *Eutetranychus orientalis* (Klein), *Aculops lycopersici* (Massee), *Eriophyes dioscoridis, Tenuipalpus granati,* and *Brevipalpus pulcher* (Afify et al., 1969; Elbadry et al. 1969a, b; El-Bagoury et al., 1989; Hafez et al., 1983; Hanna and Shereef, 1981; Rasmy et al. 1987). These studies demonstrated that *A. exsertus* could be used as an effective biocontrol agent for certain pest mites.

Citrus red mite, *Panonychus citri* (McGregor), is one of the most important citrus pests throughout the world, including China (He et al., 1989; Tan and Huang, 1989; Yue and Lei, 1990). Although many phytoseiid mites have been shown to be effec-

Table 1. Stages and numbers of citrus red mite used for feeding preference trials by *A. exsertus.*

Treatment	Egg	Larva and nymph	Adult male
1	40	10	5
2	10	40	5
3	5	10	40
4	30	10	15
5	10	30	15
6	15	40	30

tive predators of *P. citri,* their numbers were often very low in chemically treated citrus groves in China (Yue, unpubl.). *Agistemus exsertus* were more abundant than phytoseiids in some groves because *A. exsertus* were less affected by pesticides (Yue, unpubl.). This paper summarizes our study of *A. exsertus* as a biological control agent of *P. citri* under laboratory and field conditions.

MATERIALS AND METHODS

Study arena. A plastic foam pad (10 cm diam. × 1.5 cm deep) saturated with water was placed in a glass petri dish (12 cm diam. × 3 cm deep) and a 10 cm diam. filter paper was placed on top of the pad. Three mature pumelo leaves, *Citrus grandis* (L.) Osbeck, were placed on each filter paper with the lower leaf surface facing up. A water saturated absorbent cotton strip was placed along the outer edge of the each leaf to prevent the mites from escaping.

Predation study. Four life stages including eggs, larvae, nymphs and adult males of citrus red mite were used as prey at densities of 5, 10, 20, 30, 40, 50 and 60 per leaf arena with nine replicates for each treatment. One *A. exsertus* was transferred onto each arena. The number of prey consumed by each *A. exsertus* was recorded under a stereomicroscope every 12 hr over a 3-d period. Predation experiments with adult females, males, and nymphs of *A. exsertus* were conducted separately at 30°C in a growth chamber. The functional response parameters, including instantaneous rate of discovery (a) and handling time (Th) as defined by Holling (1959), were calculated.

Prey preference study. Pumelo leaf arenas were used for prey preference studies. *P. citri* adult females were transferred onto each arena for 24 hr to obtain eggs. Nymphs and adult males of *P. citri* were subsequently transferred. The numbers for each mite stage in each arena varied with six treatments (Table 1). There were three replications for each treatment. One *A. exsertus* adult female was placed onto each arena and the numbers of prey consumed by each predator was recorded once a day. The tests were conducted for three days at 27°C in a growth chamber.

Life table data. Recently matured leaves of sweet orange, *Citrus sinensis* Osbeck (L.), were used to rear citrus red mite. Each leaf was divided into two arenas by placing an absorbent cotton strip perpendicularly across the midrib. One newly emerged larva was transferred onto each arena using a fine brush under a stereomicroscope. Sixty larvae were reared at each of 15, 20, 25, 30 and 35°C. Survivorship and the number of eggs laid by each female were recorded once a day until

Table 2. The functional response parameters of *A. exsertus* to *P. citri* at 30°C.

Predator	Prey	Instantaneous rate of discovery (a)	Handling time (hr) (Th)
Female	Egg	1.430	1.67
Female	Nymph	0.335	4.66
Female	Male	0.172	2.29
Male	Egg	0.227	1.16
Nymph	Egg	0.102	4.32

death of female. *A. exsertus* was also reared at the same temperatures on sweet orange leaf arenas infested with citrus red mite eggs. Intrinsic rates of natural increase (rm), as defined by Birch (1948), were calculated using the life table data of both species.

Release experiment and field investigation. Four potted sweet orange plants, each with only 20 selected leaves, were used for release experiments in the greenhouse at 25 ± 2°C. Citrus red mite and *A. exsertus* reared in the laboratory were used for the release experiments. One hundred newly emerged adult females of citrus red mite were transferred onto each potted plant with a fine brush. Ten young adult females of *A. exsertus* were transferred onto each of two of the four citrus plants. The other two plants were served as controls. Observations were made every four days using a 10× hand lens and the numbers of motile stages of both prey and predator were recorded for a period of 35 days.

The field study was carried out bi-weekly in a sweet orange (*C. sinensis*) grove. Eighty leaves were collected randomly on each sampling date, and the leaf samples were observed under a stereomicroscope in the laboratory. *A. exsertus, P. citri,* and *Eotetranychus kankitus* Ehara, as well as all phytoseiids, were recorded. The biweekly samplings were taken over a period of ten months.

A study of the age composition of *P. citri* in the field was conducted in the winter (January and February) and spring (April and May). Five sweet orange trees were sampled weekly, and 20 leaves were collected randomly from each tree. The adults, immatures, and eggs were recorded.

RESULTS

Agistemus exsertus preyed upon eggs and other motile stages of *P. citri. A. exsertus* adult females had the higher instantaneous rate of discovery (a = 1.430) and shorter handling time (Th = 1.67 hr) when provided with *P. citri* eggs as compared to other prey stages (Table 2). On the other hand adult males of this predator had the shorter handling time (Th = 1.16 hr) and lower instantaneous rate of discovery (a = 0.227) than that of adult females. In comparison with the adults of both sexes, *A. exsertus* deutonymph had the lowest instantaneous rate of discovery (a = 0.102) and longest handling time (Th = 4.32 hr) when citrus red mite eggs were provided as prey (Table 2). *A. exsertus* clearly exhibited a prey preference when eggs, nymphs, and adult males of *P. citri* were provided as preys in same arena. It was found that an average of 75.2% of prey consumed by *A. exsertus* adult females were mite eggs as compared to consumption of only 16.6 and 8.2% by nymphs and adult males,

Table 3. Life stages of *P. citri* and *E. kankitus* preferred by *A. exsertus* adult females.

Life stage	Percentage in total prey consumption	
	P. citri	*E. kankitus*
Adult male	8.2	6.8
Nymph	16.6	18.9
Egg	75.2	74.3

respectively (Table 3). Under natural conditions, the number of citrus red mite eggs was consistantly found to be higher than the other life stages in spring and winter months (Table 4).

The intrinsic rates of natural increase (rm) for both prey (*P. citri*) and predator (*A. exsertus*) at five constant temperatures are given in Table 5. At 15°C, the rm values for both prey and predator were similar. *A. exsertus* had a slightly higher rm at 20 and 25°C than that of *P. citri.* In contrast, at 30 and 35°C the rm values for *P. citri* were higher than the values of *A. exsertus* (Table 5).

Figure 1 shows the results of release experiment on potted plants. The number of citrus red mite reached a total of 475 after 17 days followed by a sharp decrease as *A. exsertus* increased. The number of *A. exsertus* was recorded at 110 on the 24th day and this was eight days after the peak of prey population. The number of citrus red mite on the control plants increased slowly during the first 12 days and then increased rapidly, reaching 830 on the 28th day.

In winter months (Dec., Jan. and Feb.) the population levels of *A. exsertus* and *P. citri* were very low (Fig. 2). *A. exsertus* were found always in association with *E. kankitus.* The population of *P. citri* increased quickly in April and May and disappeared after June (Fig. 2). The dramatic increases of *A. exsertus* were observed from May to October when they coincided with the increase of another natural prey, *E. kankitus* (Fig. 2).

DISCUSSION

We have observed that *A. exsertus* preyed upon various life stages of *P. citri.* However, it clearly preferred to feed on citrus red mite eggs. When fed with citrus red mite eggs, *A. exsertus* had a shorter development time, longer longevity and higher reproductive rate than when they were fed on other immature stages (Hanna and Shereef, 1981; Hafez et al., 1983; Osman and Zaki, 1986; El-Bagoury et al.,

Table 4. The age composition (%) of citrus red mite in spring and winter months.

Time	Egg	Larva and nymph	Adult
April, 1987	60.51	29.62	9.87
May, 1987	53.08	36.18	10.74
Jan, 1988	65.77	27.63	6.60
Feb, 1988	62.31	31.39	6.30
Jan, 1989	73.69	19.24	7.07
Feb, 1989	80.58	15.42	4.00

Table 5. Comparison of intrinsic rate of natural increase (rm) for *P. citri* and *A. exsertus.*

Temperature (°C)	*P. citri*	*A. exsertus*
15	0.071	0.070
20	0.154	0.165
25	0.196	0.229
30	0.256	0.211
35	0.248	0.226

1989). Under field conditions, we noted that citrus red mite eggs were always more abundant than its immature and adult stages. Our study showed that eggs accounted for 61% and 53% of the total *P. citri* populations in April and May, respectively, and remained at 62–81% from January to February (Table 4). Therefore it is reasonable to assume that preying on the eggs is an advantageous strategy for *A. exsertus* as this predator is not as agile as phytoseiids.

Because of its life-stage preference *A. exsertus* can coexist with phytoseiids in the same habitat. We have found that citrus red mite in unsprayed groves was controlled by both *A. exsertus* and phytoseiids (Yue, unpubl.). We have also noted that *A. exsertus* was always more abundant than phytoseiids, especially in late summer and fall in the chemically treated groves because this predator is more tolerant to pesticides (Yue, unpubl.). The results showed that the efficiency of prey consumed by *A. exsertus* was dependent on the life stages of prey and predator as well as environmental temperature. In laboratory tests, one adult female of *A. exsertus* consumed as many as 12 citrus red mite eggs per day. The results of our greenhouse release

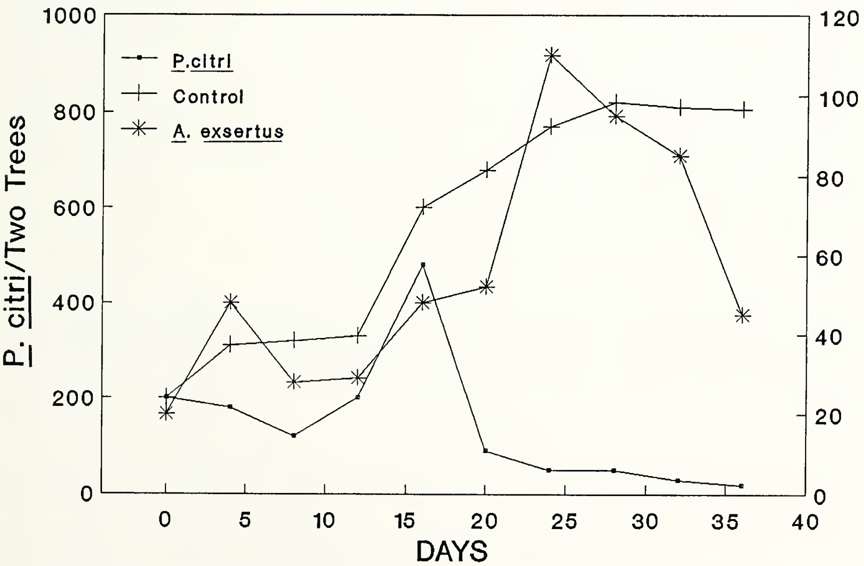

Fig. 1. Control of *Panonychus citri* by *Agistemus exertus* on potted citrus plants.

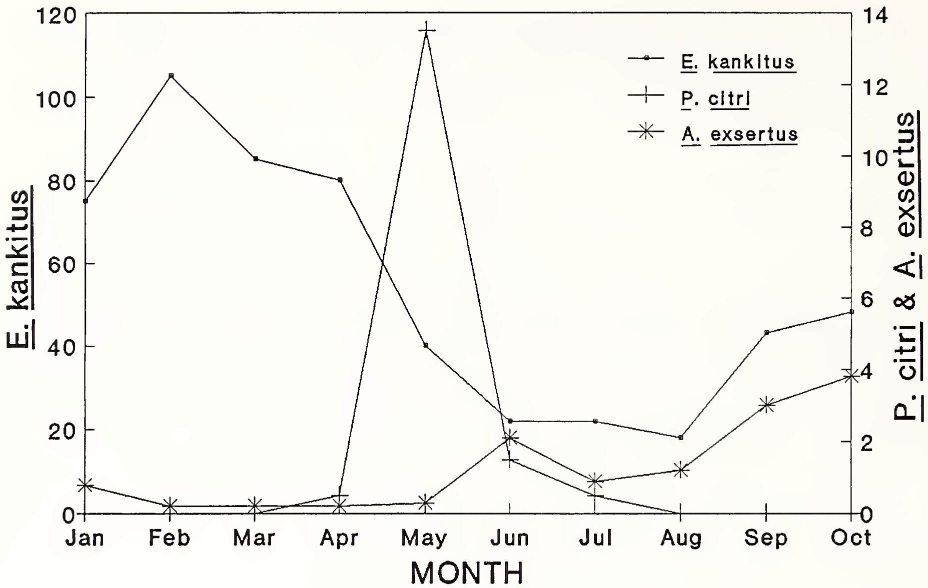

Fig. 2. Population dynamics of *Agistemus exertus* and its prey *Panonychus citri* and *Eotetranychus kankitus* in citrus grove.

experiment showed that citrus red mite was controlled after 20 days with a prey–predator ratio of 10:1 (Fig. 1). In citrus groves, citrus red mite populations built up very quickly in late spring and early summer. *A. exsertus* alone probably would not control citrus red mite. However, *A. exsertus* could play an important role in controlling the citrus red mite along with phytoseiids and other natural enemies. In the spring and winter months, the citrus red mite was mostly found to be at the egg stage which is a preferred food for *A. exsertus*. Therefore, *A. exsertus* could exert a great pressure on the prey population. In summary, we fell that *A. exsertus* can be used as a biocontrol agent for controlling the citrus red mite in conjunction with other predators in an integrated pest management program.

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